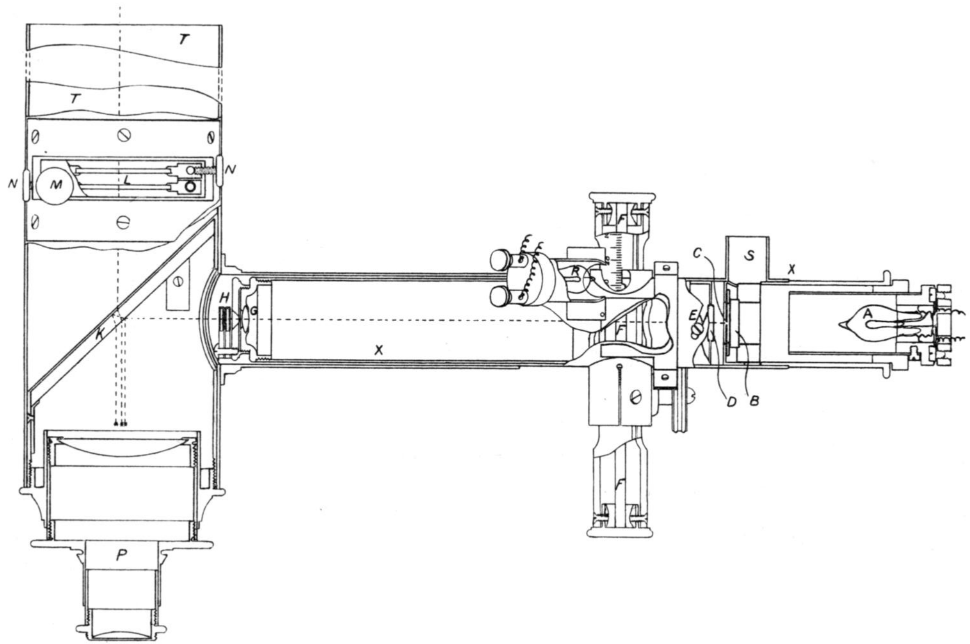

THE RUMFORD PHOTOMETER OF THE LICK OBSERVATORY.

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INVESTIGATION OF THE RUMFORD PHOTOMETER OF THE LICK OBSERVATORY.

BY JAMES D. MADDRILL.

About five years ago, a photometer of new type, devised by Professor E. C. PICKERING, and constructed with the aid of the Rumford Fund of the American Academy, was received at the Lick Observatory. It was planned with special reference to convenience of use and reduction.

The telescope objective forms an image of a star in the focal plane of the ocular P (see illustration). An artificial star is formed beside this, by the system: lamp A, pin-hole diaphragm C, ground-glass D, projecting-lens G, and diagonal plane glass reflector K. The image reflected by the back surface of the diagonal plate is not used, except to aid the observer in bringing the images of different real stars successively to the same position relatively to the artificial star. The artificial star can be made to resemble the real star image in size by adjusting the distance of the ground-glass D from the diaphragm C, and also by moving the lamp A toward or away from the diaphragm. D is movable longitudinally by a lateral motion of the screw E in an inclined slot. The blue-glass B gives the artificial star the color of the "average" real star. The brightness of the artificial star can be varied at will by moving a "wedge" F of photographic film, which cuts off a part of the light by absorption and reflection, the variation in magnitude being nearly proportional to the displacement of the wedge. The wedge has a range of about four and a half magnitudes. If the artificial star is too bright for comparison with a real star, one or both of the shades H can be interposed in the cone of rays, and the light reduced about two or four magnitudes, respectively. If the artificial star is not bright enough, the brightness of the real star image can be diminished by using

one or both shades L, or, if necessary, by cutting down the aperture of the telescope.

To determine the magnitude of a star x, the artificial star is made equal to it in brightness and the position of the wedge is read from a graduated scale. The artificial star is then compared with a neighboring star of known magnitude and the wedge-scale reading taken. Progressive light changes in the artificial star are practically eliminated by immediate repetition of comparisons in the reverse order. The difference of magnitude between x and the standard star is obtained by converting the difference of scale-readings into magnitudes.

Preliminary measures of standard stars by Dr. AITKEN early showed that the change of absorption per scale-division was not the same at different parts of the wedge, and that an absorption-curve or table would be required to obtain results of the accuracy desired. The measures also showed that the determination of such a curve from stars would demand a very large number of settings. At the suggestion of Director CAMPBELL, the photometer was taken to Berkeley for measures on the Lummer-Brodhun laboratory photometer, kindly placed at our disposal by Professor SLATE. One side of the screen was illuminated by light passing through the wedge, and the other side by light from an illuminated surface whose distance could be changed and measured. The wedge absorption was determined at scale-divisions 0, 5, 10, . . . to the end at 65. The following values of the absorption relative to the absorption at scale-reading 0, resulted:—

Wedge.	Rel. Abs. in Mag.	Wedge.	Rel. Abs. in Mag.
0	0.000	35	2.556
5	0.045	40	3.002
10	0.414	45	3.370
15	0.968	50	3.577
20	1.421	55	3.612
25	1.772	60	2.54
30	2.108	65	0.02

The measures very closely resemble those made on this wedge by three observers at Harvard College Observatory before the photometers were sent out. But the curve differs considerably in slope (or average value of change of absorption per division) from the value found by Dr. AITKEN from

star measures. The phenomenon is probably due to the different effect on points and surfaces of the diffusion by the silver grains of the wedge. Varying the apparatus in the laboratory, it was found that the slope was affected, but that the form of the curve was not. That is, all the curves could be obtained from any one by a simple "stretching" of the curve in the direction representing change of absorption.

A number of measures of *Pleiades* stars were accordingly made by Dr. AITKEN to obtain data for the determination of the "stretching factor" to be applied to the curve of relative absorption tabulated on page 122. The measures gave $f = +0.261 \pm 0.011$. It was found that change of aperture or use of shades affected f, a somewhat larger value resulting when the aperture was cut down or when the shades L were used. The physiological effect of change of background seems to be different for stars of different brightness. The value $+0.261$ is a mean value adopted for apertures larger than six inches, with or without shades. Differences of magnitude, measured with any combination of apertures—over six inches—and shades, will not be more than one or two per cent in error if the reduction employs the curve obtained by increasing each tabulated value (p. 122) by 0.261 of itself. The result of this stretching is given in the following table, in which the thousandths have been dropped and the relative absorption, m, interpolated for each division, d:—

TABLE OF m WITH ARGUMENT d.

d	00	10	20	30	40	50
0	0.00	0.52	1.79	2.66	3.79	4.51
1	0.00	0.67	1.89	2.76	3.90	4.54
2	0.00	0.82	1.98	2.87	4.00	4.56
3	0.01	0.96	2.07	2.99	4.09	4.57
4	0.02	1.10	2.15	3.10	4.17	4.57
5	0.05	1.22	2.23	3.22	4.25	4.56
6	0.10	1.34	2.31	3.33	4.32	*
7	0.17	1.46	2.39	3.45	4.38	*
8	0.26	1.57	2.47	3.57	4.43	*
9	0.38	1.68	2.56	3.68	4.47	*
10	0.52	1.79	2.66	3.79	4.51	*

A careful examination of the absorption of the shade-glasses, made with the laboratory photometer, gave for the

shades L: I, $0^m.89$; I and II, $1^m.75$. It has never been found necessary here to use both shades H, the shade No. 2, nearest the projecting-lens, being sufficient to extinguish the artificial star at high readings of the wedge. The absorption of this shade is $1^m.72$.

The practical range of the photometer for direct comparisons is about 7½ mag., from about 9½ mag. to 17 mag., with the 36-inch refractor, and from about 6½ to 14 mag. with the 12-inch. By a recent modification of the telescoping adapting-tube AX' (since the drawing here reproduced), by which the lamp A can be moved about an inch closer to the diaphragm C than before, the range of direct comparison can be shifted about 1½ mag. in the direction of increased brightness. If a brighter lamp A were practicable, so that both shades H would be required to extinguish the artificial star, the range would be further increased to include stars 1½ mag. brighter. The present available battery capacity is barely sufficient for the lamp we are now using.

The following example will illustrate the method of reduction I have been using. The stars *a, b, c,* etc., are stars in the vicinity of *R Draconis.* The measures were made with the 36-inch refractor by Dr. AITKEN, 1903, August 19th. *d* is the mean of two sets of four settings each on the stars *a, b, c, d, e;* of three sets of four settings each on the stars *q, r, s, t, u.* *m* is taken from the table. Columns nine and ten indicate the accuracy to be expected. The Roman numerals indicate the shades L used. In the fifth column a constant, *k*, is introduced to convert the differential measures to absolute magnitudes based on the system of provisional magnitudes *M*. The last two columns give the results of similar measures made by the same observer on two other nights.

*	*d*	*m*	Shades.	Obs.	*M*	*k*	Obs. Mag.	Mean Range. Setting *d*	Mean Range. Mag. *m*	Aug. 20th.	Aug. 21st.
a I II	10.60	0.61	1.75	*k* — 1.14 =	11.12	12.26	11.51	± 1.2	± 0.18	11.52	11.45
b I II	12.78	0.93	1.75	— 0.82	11.82	12.64	11.83	0.9	.12	11.76	11.87
c I II	14.51	1.16	1.75	— 0.59	12.20	12.79	12.06	1.2	.14	12.29	12.17
d I II	18.66	1.64	1.75	— 0.11	12.38	12.49	12.54	0.7	.08	12.29	12.31
e I II	16.16	1.36	1.75	— 0.39	12.67	13.06	12.26	0.6	.07	12.31	12.40
								Mean	.12		
q —	38.87	3.67	—	+ 3.67	....	....	16.32	1.6	.18	16.53	16.41
r —	40.37	3.83	—	+ 3.83	....	....	16.48	1.4	.15	16.71	16.45
s —	43.13	4.10	—	+ 4.10	....	....	16.75	1.7	.14	16.69	16.67
t —	44.14	4.18	—	+ 4.18	....	....	16.83	0.8	.06	16.77	16.68
u —	47.99	4.43	—	+ 4.43	...	....	17.08	2.2	.10	17.00	17.01
					Mean *k* =	12.65		Mean	.13		

A discussion of all the observations made by the author that are suitable for determination of probable error shows the probable error of a single determination, based on two sets of four settings each on a star, to be ± 0.050 mag.

MT. HAMILTON, July 31, 1905.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1905.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter,	Sept.	5,	8^h 9^m P.M.	First Quarter,	Oct.	5,	4^h 54^m A.M.
Full Moon,	"	13,	10 10 A.M.	Full Moon,	"	13,	3 3 A.M.
Last Quarter,	"	21,	2 13 P.M.	Last Quarter,	"	21,	4 51 A.M.
New Moon,	"	28,	1 59 P.M.	New Moon;	"	27,	10 58 P.M.

The Sun reaches the autumnal equinox and crosses the equator from north to south at about 9 A. M. September 23d, Pacific time.

Mercury passed inferior conjunction with the Sun August 29th and became a morning star. At the beginning of September it is still too close to the Sun to be seen, but it moves rapidly away and reaches greatest west elongation September 15th. Its apparent distance from the Sun is then 17° 54′. This is considerably less than the average, because the planet is then near its perihelion, which it passes a little more than two days later. However, the planet is near a part of the ecliptic which is several degrees north of the Sun's position, and is in the part of its orbit which is north of the ecliptic. The two causes to a large extent compensate for the small elongation, and the planet can be seen in the morning twilight for a fortnight or more about the time of greatest elongation. At that time it rises fully an hour and a half before sunrise, and the interval is more than an hour for a week or so before and after September 15th, the date of greatest elongation.

Venus is a morning star, rising more than three hours before sunrise on September 1st. The interval shortens to less than three hours by October 1st, and at the end of the month it is only a little more than two hours. Since the planet